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DEVELOPMENT OF ANISOTROPIC THERMAL TRANSPORT MATERIAL

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Final Report

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14. ABSTRACT

The resources provided by this award allowed for the development of two thermally conductive nanofillers whose production at large scale was not previously possible. These fillers, pristine graphene and functionalized boron nitride, have high thermal conductivity coupled with an extreme aspect ratio, making them strong candidates for thermally conductive composites. In the past, the insolubility of pristine graphene required the use of either graphene oxide (GO) or reduced graphene oxide (rGO). While providing solubility, the oxidation also severely reduced the thermal conductivity of the material. The methods developed in the work supported by this grant allow for the use of un-oxidized and un-damaged graphene for thermal composites and include the use of a self-assembling solvent mixture and an interfacial trapping method. Boron nitride was exfoliated for the first time in large quantities. Boron nitride, unlike graphite, is electrically insulating and thus is a complimentary material to graphene. A thermal functionalization and exfoliation procedure was developed and a manuscript describing the work is currently being reviewed. Together, these new materials provide the foundation for a new class of thermally conductive composite materials. Details of the work preformed are availabl

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Accomplishments (200 word max): The resources provided by this award allowed for the development of two thermally conductive nanofillers whose production at large scale was not previously possible. These fillers, pristine graphene and functionalized boron nitride, have high thermal conductivity coupled with an extreme aspect ratio, making them strong candidates for thermally conductive composites. In the past, the insolubility of pristine graphene required the use of either graphene oxide (GO) or reduced graphene oxide (rGO). While providing solubility, the oxidation also severely reduced the thermal conductivity of the material. The methods developed in the work supported by this grant allow for the use of un-oxidized and un-damaged graphene for thermal composites and include the use of a self-assembling solvent mixture and an interfacial trapping method. Boron nitride was exfoliated for the first time in large quantities. Boron nitride, unlike graphite, is electrically insulating and thus is a complimentary material to graphene. A thermal functionalization and exfoliation procedure was developed and a manuscript describing the work is currently being reviewed. Together, these new materials provide the foundation for a new class of thermally conductive composite materials. Details of the work preformed are available in the archival publications and PhD thesis supported by the award.

Archival publications (published) during reporting period:

1) Oyer, A. J.; Adamson, D. H.; "Synthesis and Characterization of Functionalized Graphene Sheets Prepared by Thermal Exfoliation" *Polymer Preprints*, **2010**, *51(2),* 648.
2) Oyer, A. J.; Adamson, D. H., "Synthesis and Surface Modification of Functionalized Graphene Sheets" *Materials Research Society National Meeting Boston*, **2010**.
3) Oyer, A. J.; Adamson, D. H.; "Differentiation of Graphene Sheets in Graphite Oxide" *Materials Research Society Cancun Meeting*, **2010**.
4) Oyer, A. J.; Dobrynin, A. V.; Asandei, A. D.; Adamson, D. H., "High Concentration Graphene Suspensions" *International Materials Research Congress XX, Cancun MX,* **2011**.
5) Oyer, A. J.; Carrillo, J.-M. Y.; Hire, C. C.; Schniepp, H. C.; Asandei, A. D.; Dobrynin, A. V.; Adamson, D. H., "Stabilization of Graphene Sheets by a Structured Benzene/Hexafluorobenzene Mixed Solvent" *Journal of the American Chemical Society*, **2012**, *134*, 5018-5021.
6) Oyer, A. J.; Carrillo, J.-M. Y.; Hire, C. C.; Schniepp, H. C.; Asandei, A. D.; Dobrynin, A. V.; Adamson, D. H., "Mixed Solvents to Exfoliate and Stabilize Graphene Sheets" *Fall ACS meeting Philadelphia*, **2012**.

7) Oyer, A. J.; Carrillo, J.-M. Y.; Hire, C. C.; Schniepp, H. C.; Asandei, A. D.; Dobrynin, A. V.; Adamson, D. H., "Mixed Solvents to Exfoliate and Stabilize Graphene Sheets" *Fall ACS meeting Philadelphia*, **2012**.
8) Oyer, A. J.; Carrillo, J.-M. Y.; Hire, C. C.; Schniepp, H. C.; Asandei, A. D.; Dobrynin, A. V.; Adamson, D. H., "Mixed Solvents to Exfoliate and Stabilize Graphene Sheets" *Fall ACS meeting Philadelphia*, **2012**.
9) Woltornist, S. J.; Oyer, A. J.; Carrillo, J.-M.; Cai, M.; Schneipp, H. C.; Dobrynin, A. V.; Adamson, D. H., "Formation of transferable transparent pristine graphene films at a solvent interface" *Spring ACS meeting New Orleans,* **2013**.
10) Woltornist, S. J.; Oyer, A. J.; Carrillo, J.-M. Y.; Dobrynin, A. V.; Adamson, D. H., "Conductive Thin Films of Pristine Graphene by Solvent Interface Trapping" *ACS Nano*, **2013**, *7(8)*, 7062-7066.
11) Oyer, A. J. "Exfoliation and Chemical Modifications of Natural Flake Graphite" *PhD Thesis*, University of Connecticut, **2013**.

Changes in research objective, if any: none

Change in AFOSR program manager, if any:
1. Jata Kumar (Kumar.Jata@aoard.af.mil) to
2. Joan Fuller (joan.fuller@afosr.af.mil) to
3. Ali Sayir (ali.sayir@afosr.af.mil)

Extensions granted or milestones slipped, if any: none

New discoveries, inventions, or patent disclosures during reporting period:

Provisional Patent – Stabilization of Graphene suspensions by a mixed solvent method
Provisional Patent – Formation of Transparent Conductive Graphene Film by Interfacial Trapping